Searches for Supersymmetry at the Tevatron

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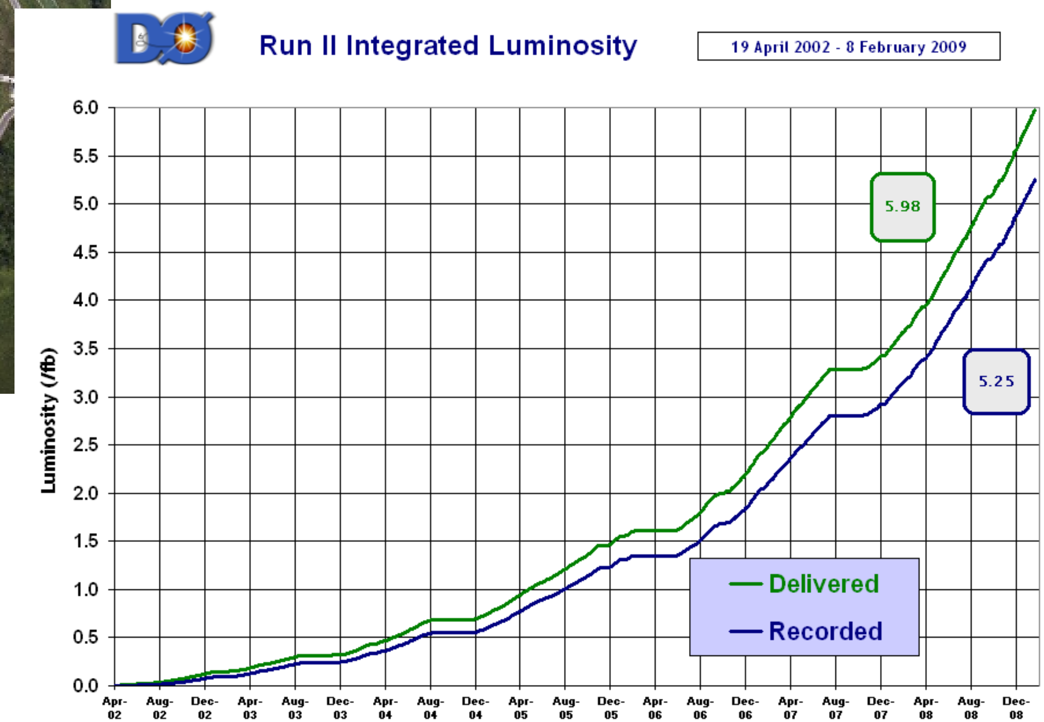
For the CDF and DØ Collaborations

Outline

- (Very) brief overview of Supersymmetry
- Trilepton searches
- Squark/gluino searches
- Stop/Sbottom searches
- GMSB diphoton searches
- Long-lived particle searches

The Tevatron Experiments

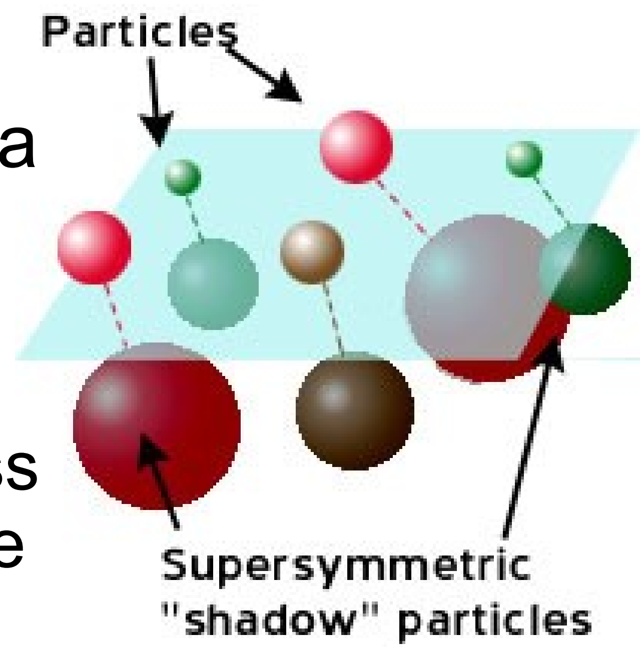
- Both CDF and DØ have recorded over 5 fb^{-1} of data, and continue to take data with ~90% efficiency
- I will concentrate on results using over 1 fb^{-1} of data



At 1.96 TeV, the Tevatron is still the world's highest energy collider, and an ideal location to search for new physics.

An Experimentalist's View of Supersymmetry

- Supersymmetry (SUSY) predicts that each standard model particle will have a SUSY partner (differing by ½ unit of spin)
  - Must be a broken symmetry, or the "sparticles" would have the ~same mass as the SM particles (and we would have seen them by now)
- SUSY phenomenology is driven by how SUSY is broken
  - Most generic has ~100 free parameters
  - Much easier to work with mSUGRA (gravity-mediated), GMSB (gauge-mediated), or other SUSY breaking models with O(5) free parameters

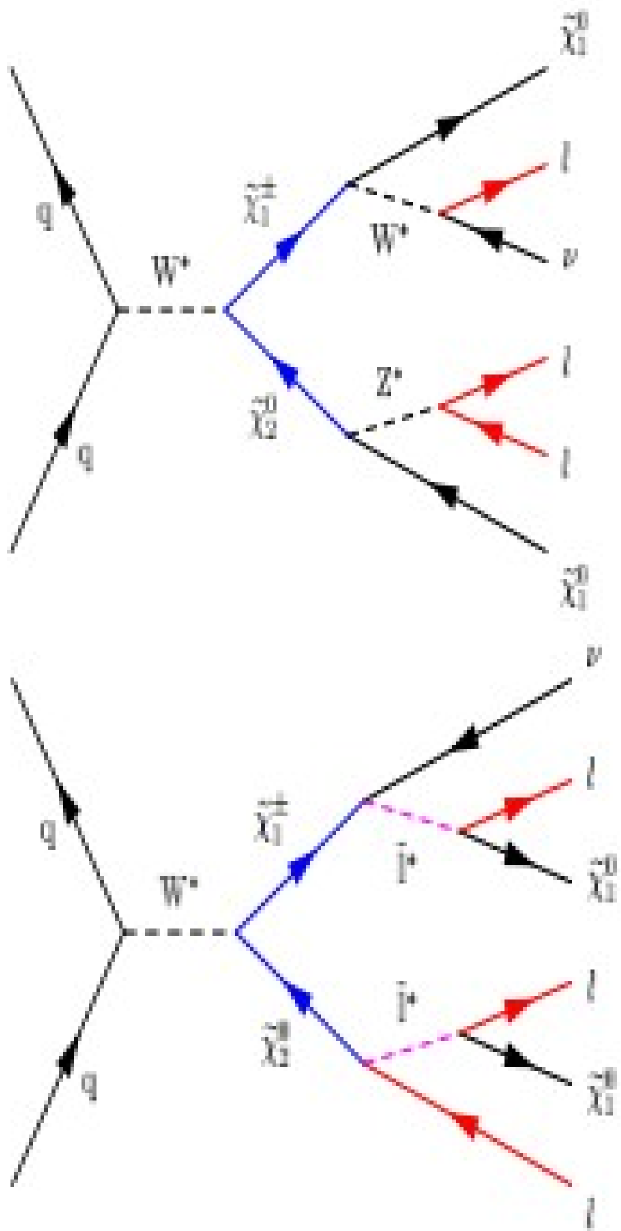


Leptons → sleptons
Neutrinos → sneutrinos
Quarks → squarks
Gauge bosons → gauginos
Higgs bosons → higgsinos
These mix to form neutralinos *and* charginos.

General SUSY Properties

- It's important to remember that SUSY models can represent a huge variety of possible signatures
- All of the analyses I present assume that *R-parity* is conserved
  - Lightest supersymmetric particle (LSP) is stable and neutral (good dark matter candidate) and will escape the detector undetected
  - Heavier SUSY particles decay to SM particles and (eventually) the LSP
  - SUSY particles are produced in pairs
  - ⇒ "typical" signature is SM particles (leptons and/or jets) and missing energy
- Additionally, most analyses presented use mSUGRA framework (exceptions will be noted)
- Many other possible signatures, such as photons+MET, long lived particles, mass resonances in dileptons, etc...

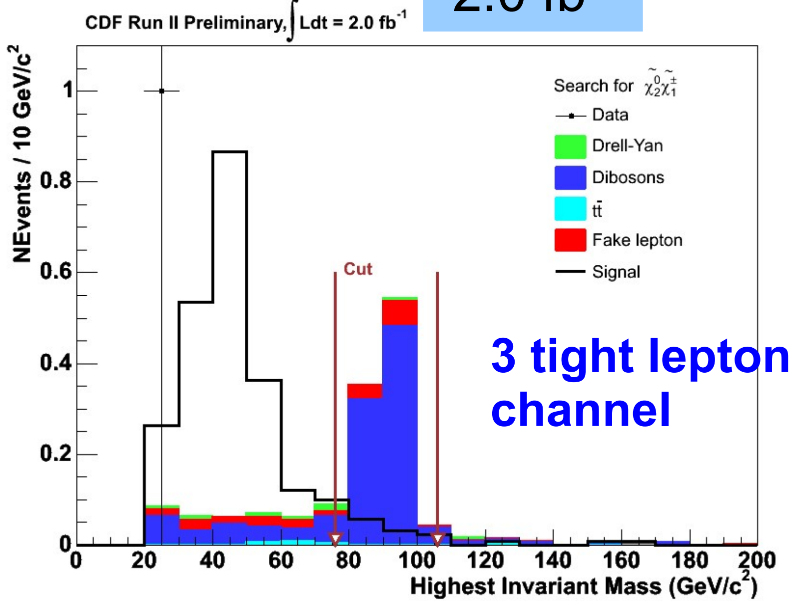
Trileptons



- Final states with leptons are “clean”
- Chargino/neutralino production typically have a relatively large cross section
- Can decay through virtual W/Z or slepton
  - Final state is 3 leptons + MET
  - Branching fraction small, but very clean final state with small backgrounds
    - Combine many final states to maximize sensitivity
  - Lepton pT depends on the mass relationships

CDF Trilepton Search (I)

2.0 fb^{-1}



- 5 separate channels (3 tight leptons, 2 tight + 1 loose, 1 tight + 2 loose, 2 tight + 1 track, and 1 tight + 1 loose + 1 track, where “lepton” means e or μ)
- Require lepton (or track) pT > 5-20 GeV, MET > 20 GeV, ΔΦ between leptons < 2.9, jet veto, Z-mass cut
- Dominant background is diboson

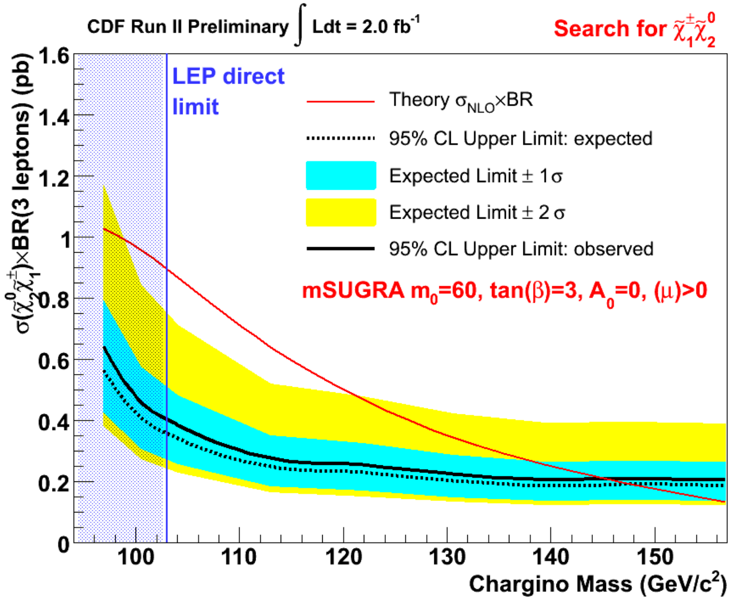
PRL **101**, 251801 (2008)

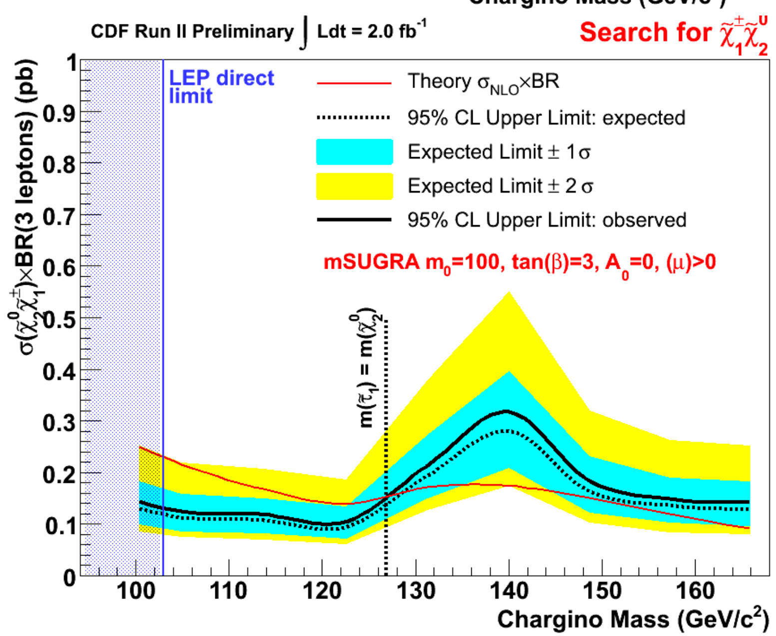
CDF RUN II Preliminary $\int \mathcal{L}dt = 2.0\ \mathrm{fb}^{-1}$: Search for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$

Channel	Signal	Background	Observed
3tight	2.25 ± 0.13(stat) ± 0.29(syst)	0.49 ± 0.04(stat) ± 0.08(syst)	1
2tight,1loose	1.61 ± 0.11(stat) ± 0.21(syst)	0.25 ± 0.03(stat) ± 0.03(syst)	0
1tight,2loose	0.68 ± 0.07(stat) ± 0.09(syst)	0.14 ± 0.02(stat) ± 0.02(syst)	0
Total Trilepton	4.5 ± 0.2(stat) ± 0.6(syst)	0.88 ± 0.05(stat) ± 0.13(syst)	1
2tight,1Track	4.44 ± 0.19(stat) ± 0.58(syst)	3.22 ± 0.48(stat) ± 0.53(syst)	4
1tight,1loose,1Track	2.42 ± 0.14(stat) ± 0.32(syst)	2.28 ± 0.47(stat) ± 0.42(syst)	2
Total Dilepton+Track	6.9 ± 0.2(stat) ± 0.9(syst)	5.5 ± 0.7(stat) ± 0.9(syst)	6

“Signal” numbers are for a particular choice of benchmark model

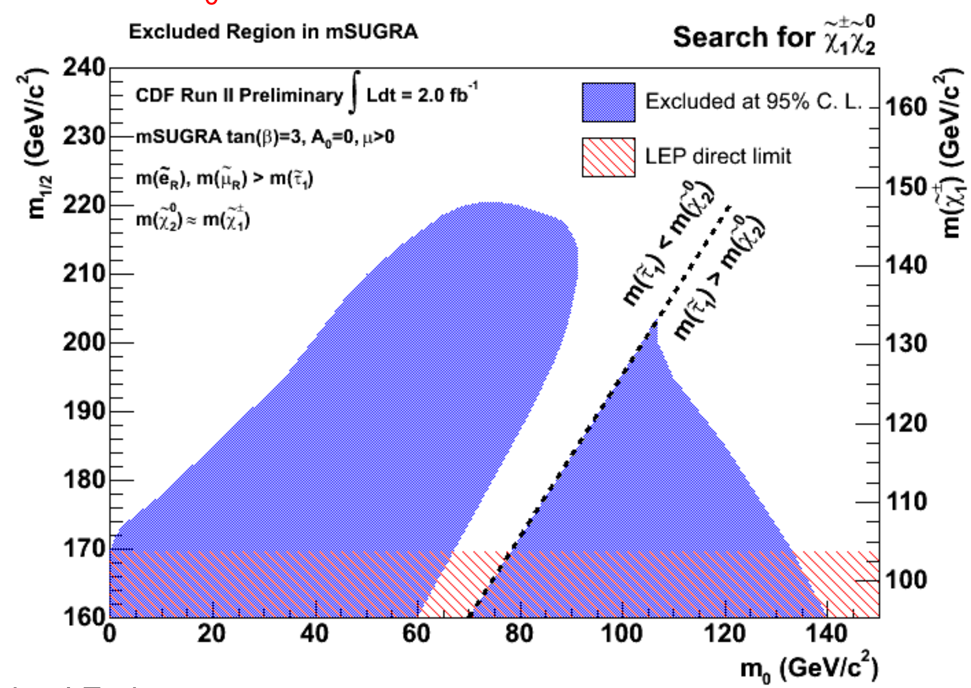
CDF Trilepton Search (II)





- Data consistent with background, set limits on
  - Mass of lightest chargino (for two specific model assumptions)
  - In the $m_0 - m_{1/2}$ plane for mSUGRA

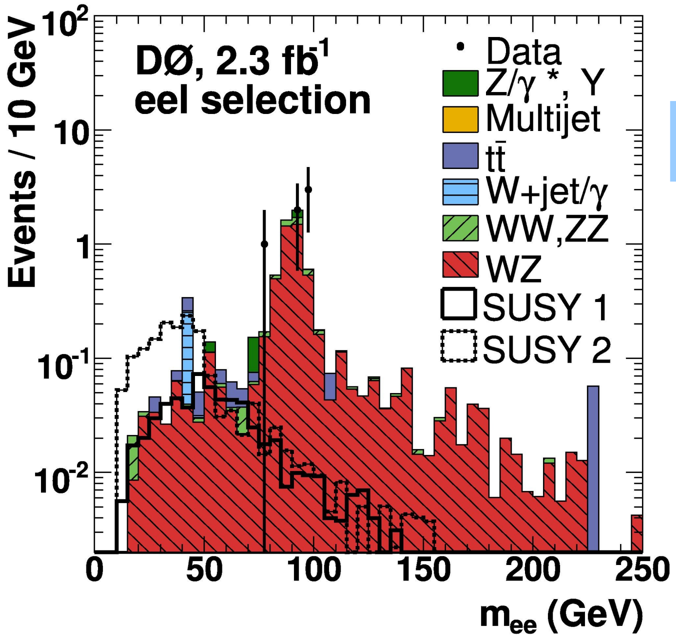
Exclude lightest chargino mass below 145.4 GeV for m_0 = 60 GeV and mass below 127.0 GeV for m_0 = 100 GeV.



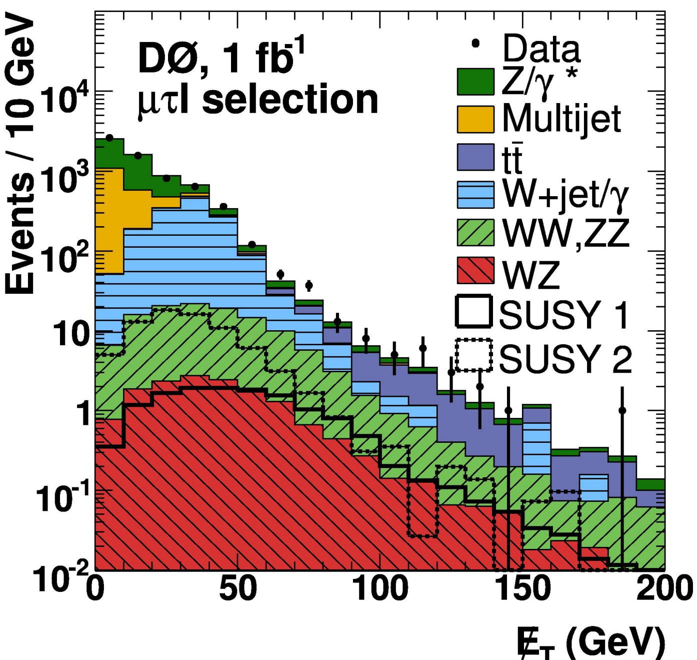
PRL **101**, 251801 (2008)

DØ Trilepton Search (I)

- Combines a μμl, μτl, eμl, μττ, and eel selection
  - l = isolated track in central tracker
  - Optimize a "high-p_T" and "low-p_T" selection for each channel
- Require lepton (or track) pT above 8-15 GeV
- Use event kinematics (MET, minv, mT, etc...) to separate from background
- Results in 0-4 background events



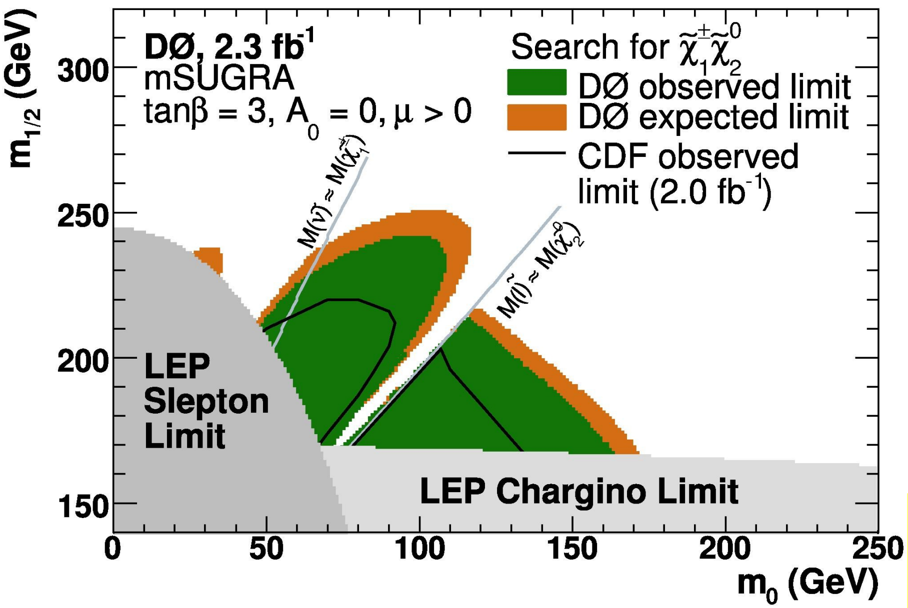
2.3 fb^{-1}



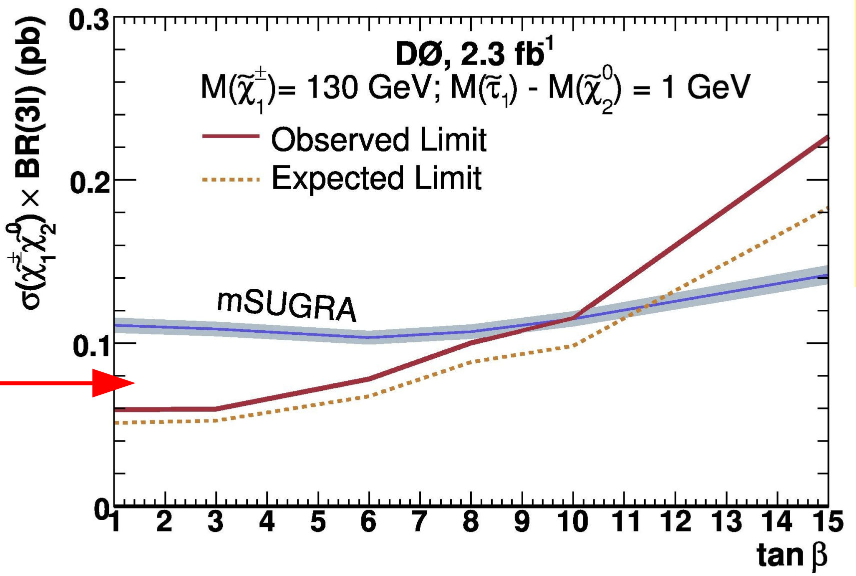
arXix: 0901.0646
Submitted to PLB

DØ Trilepton Search (II)

- Signal efficiency in each channel varies between 1% and 5%
- Observed events are consistent with the predicted background, so limits are set
  - On mass of lightest chargino for several choices of parameters
  - In the $m_0 - m_{1/2}$ plane for mSUGRA
  - mSUGRA limits depend on value of tan β, stable (within factor of 2) up to 10



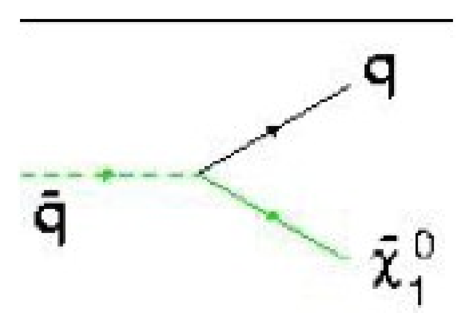
Exclude lightest charginos up to 130GeV for tan β up to 9.6

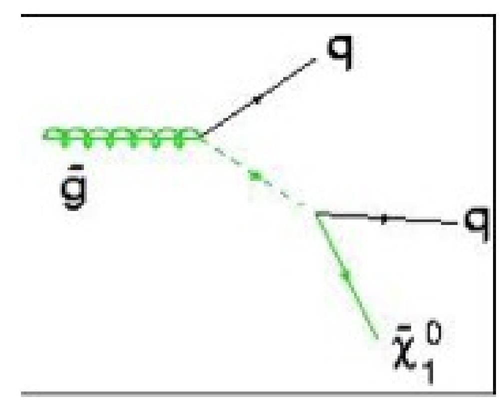


arXix: 0901.0646
Submitted to PLB

Squarks/Gluinos

- Squarks/gluinos strongly produced
- Decay to quarks and LSP
  - ⇒ signature is multiple jets and missing energy
- The exact number of jets produced (and the p_T of these jets) is determined by the mass relationships between squarks and gluinos
  - $M_{squark} < M_{gluino}$ ⇒ produce squark pairs, each decay to quark + LSP
  - $M_{gluino} > M_{squark}$ ⇒ produce gluino pairs, each decay to 2 quarks + LSP
  - $M_{squark} \approx M_{gluino}$ ⇒ can produce squark+gluino
- ⇒ Can produce 2, 3, or 4 (or more) jets (with missing energy from the LSP)



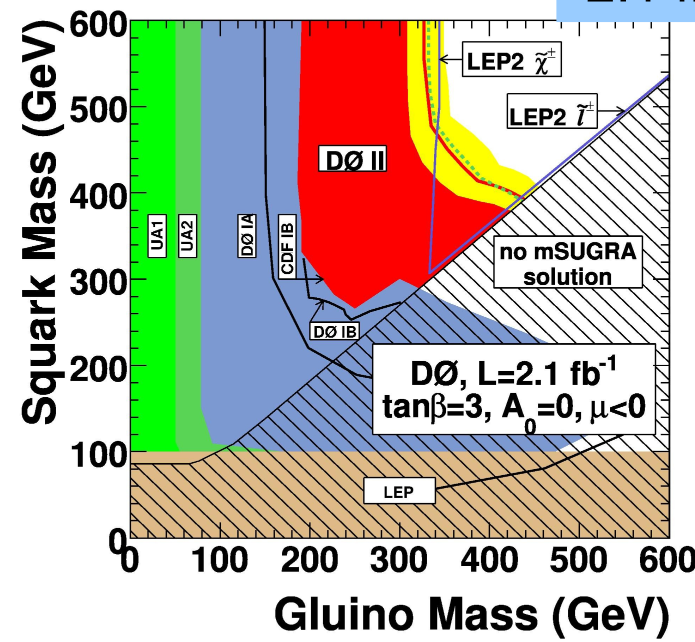


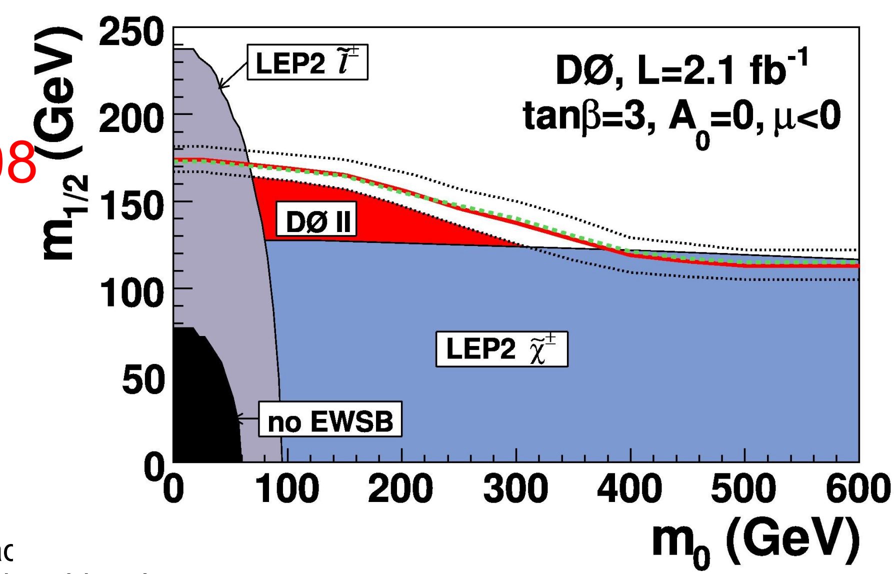
DØ Squark/Gluino Search

PLB **660**, 449 (2008)

- Divided into 2/3/4 jet (+ MET) channels, require jets above 35 GeV, H_T above 300-400 GeV, and MET above 100-200 GeV
- Selects 11/9/20 events, consistent with background estimates
  - Expect ~10 signal events
  - Main backgrounds from Z+jets, W+jets, and ttbar
- Limits set on squark and gluino masses, and mSUGRA parameters
  - Exclude squarks masses below 379 GeV and Gluino masses below 308 GeV in most conservative hypothesis
  - Exclude masses up to 390 GeV for $M_{squark} \approx M_{gluino}$

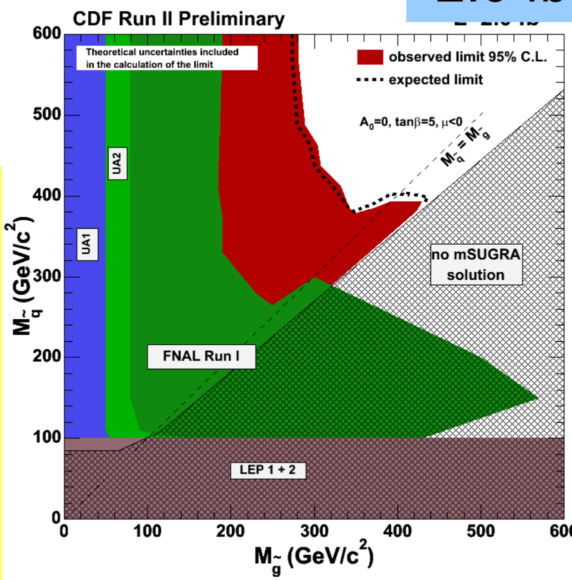
2.1 fb^{-1}



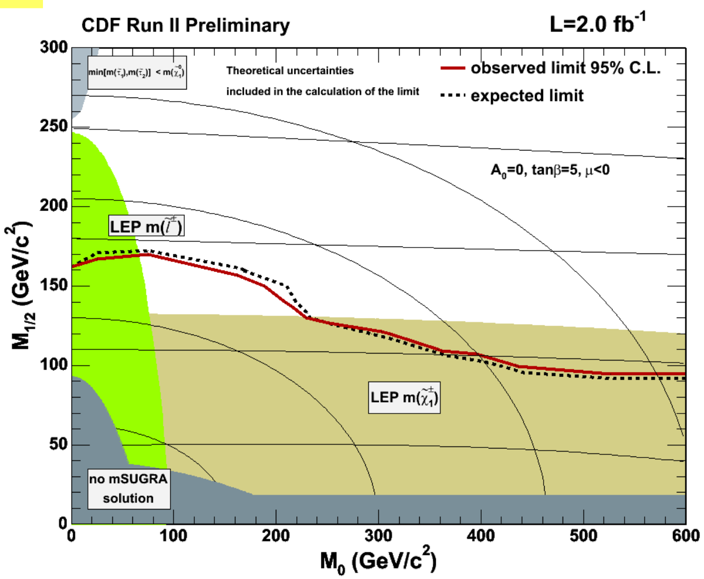


CDF Squark/Gluino Search

$2.0\ fb^{-1}$



arXiv: 0811.2512
Accepted by PRL

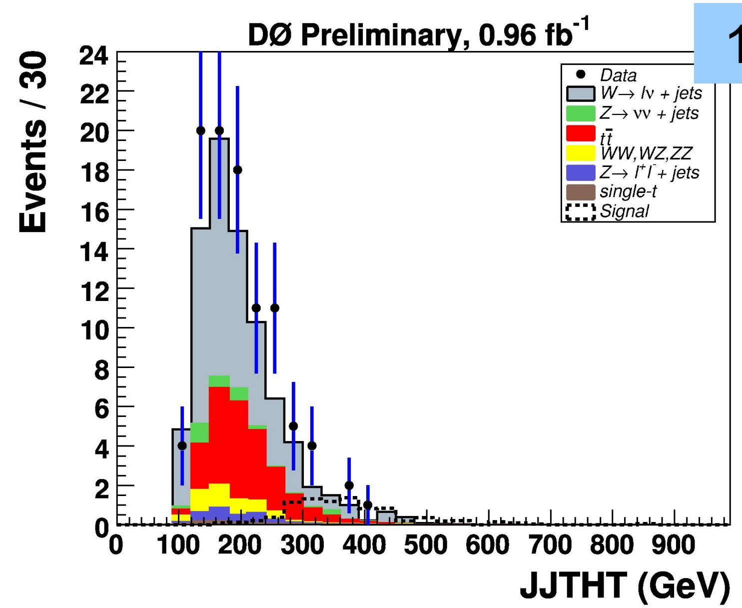


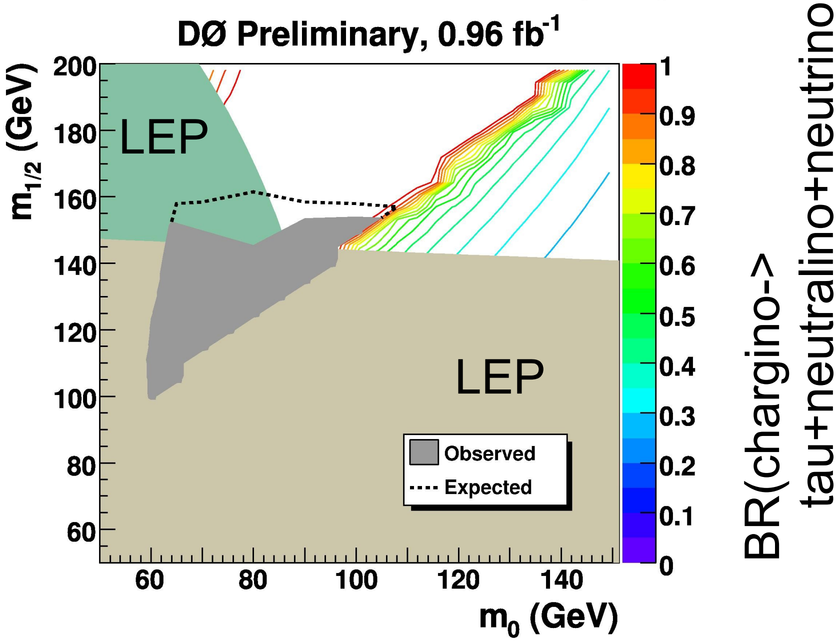
- Divided into 2/3/4 jet (+ MET) final states
- Require jets above 55-165 GeV, MET above 90-180 GeV, H_T above ~300 GeV
- Select 18/38/45 data events, with 16±5/37±12/48±17 expected background events
  - Background dominated by multijets and W/Z+jets
- Set limits on squark and gluino masses, as well as on mSUGRA parameters
  - Exclude masses up to 392 GeV for $M_{squark} \approx M_{gluino}$
  - Exclude gluino masses up to 280 GeV for all squark masses examined
  - Exclude gluino masses up to 423 GeV for squark masses below 378 GeV

DØ Squarks in jets+τ

- Search for a pair of squarks, which (eventually) decay to two (or more) jets and at least one tau (that decays hadronically)
  - Taus important at low slepton mass or high tan β
- Require jet > 35 GeV, tau > 15 GeV, MET > 175 GeV, H_T > 325 GeV
- Observe 2 data events (consistent with background) while expecting ~5 signal events
- Set limit in $m_0 - m_{1/2}$ mSUGRA plane

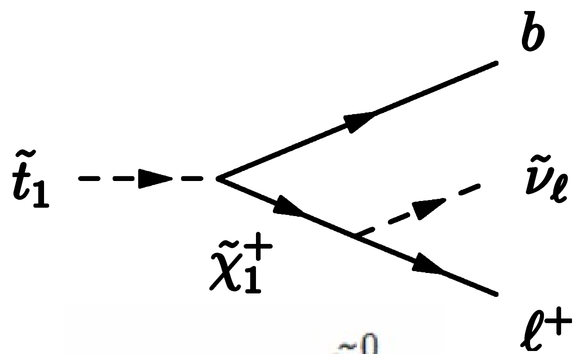
1.0 fb^{-1}

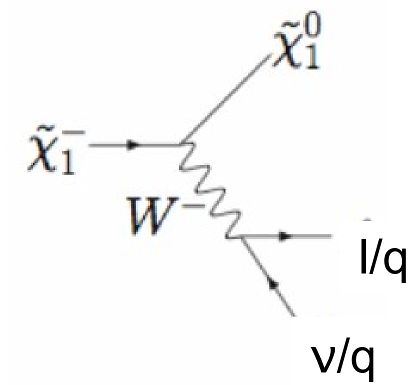


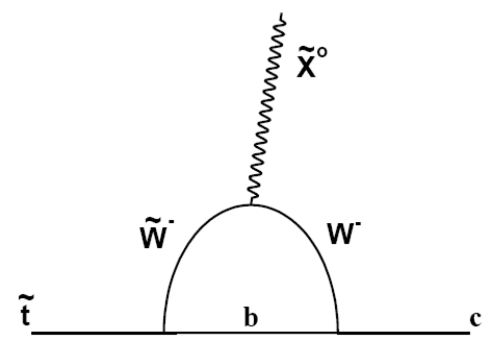


Stop/Sbottom Searches

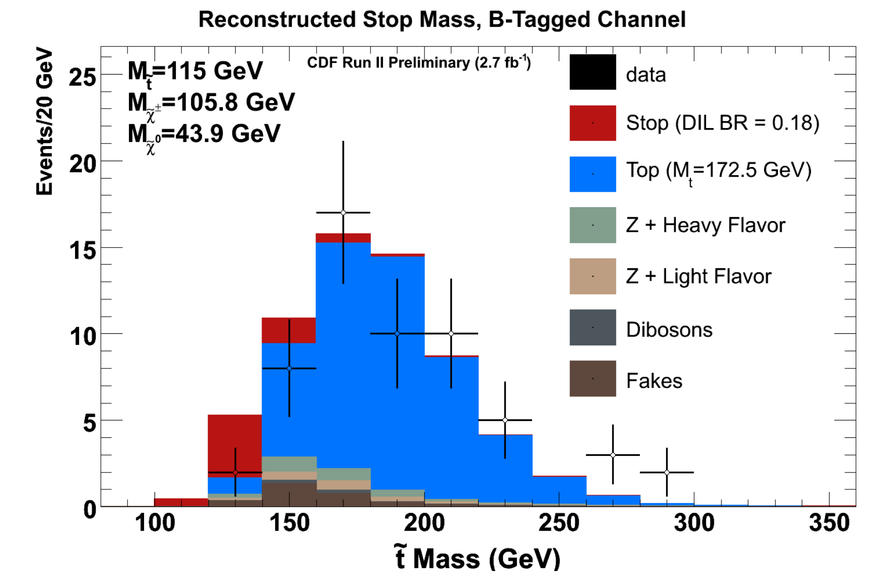
- Due to mixing, the 3rd generation squarks and sleptons should be the lightest
  - Since stops/sbottoms are lighter than the other squarks, they should have the largest production cross section among the squarks
  - The decays of the stop and sbottom depend on various mass relationships
  - Possibilities for stop (assuming it is lighter than the top) include
    - Stop → *c* + neutralino
    - Stop → *b* + lepton + sneutrino
    - Stop → *b* + W + neutralino
  - Each decay results in a different signature

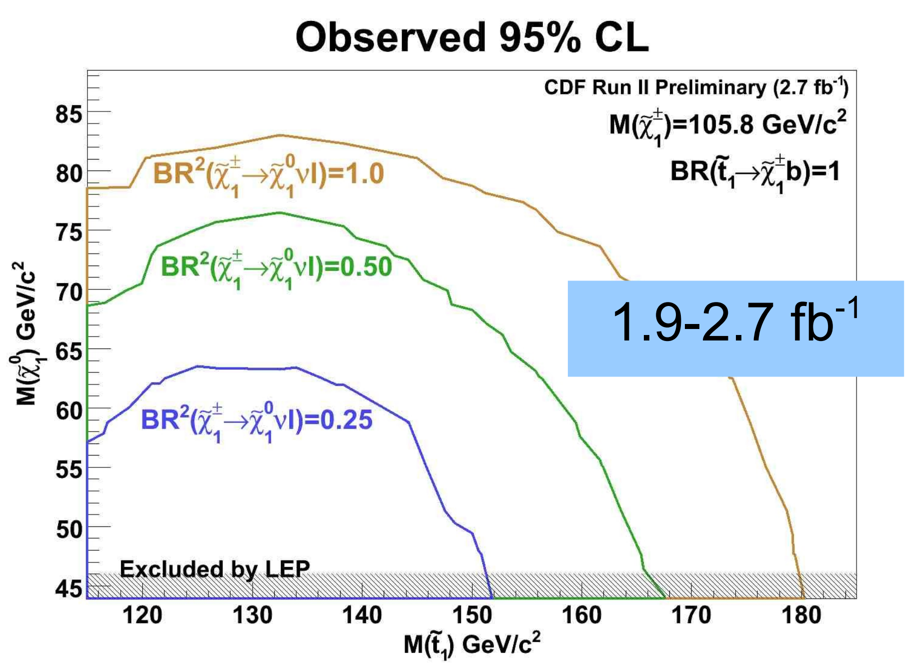






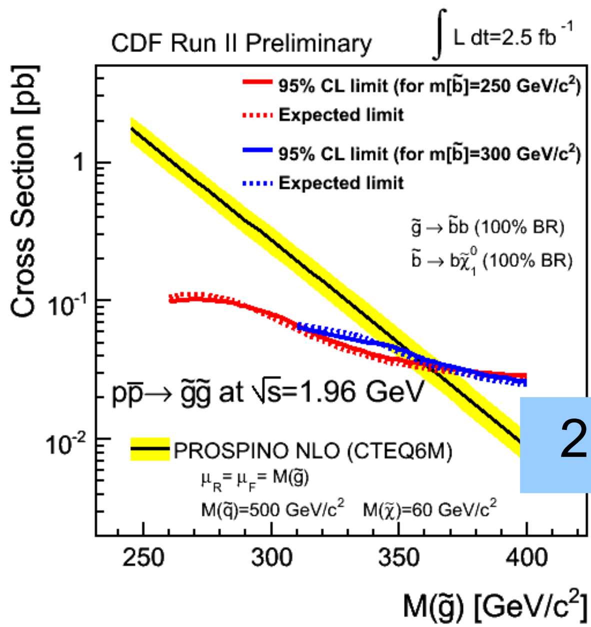
CDF stop in dileptons



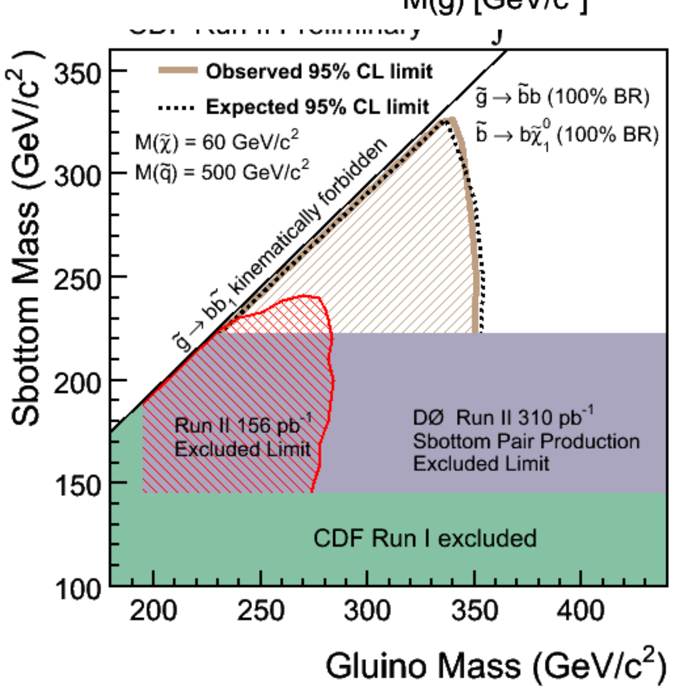


- Assume 2 stops produced, each decay to *b*+*l*+*ν*+neutralino
  - Assume stop lighter than top, all other squarks/sleptons heavy, and stop decays exclusively to *b* + chargino
  - Mimics top dilepton channel
- Require e/μ > 20 GeV, MET > 20 GeV, jets > 12-20 GeV, b-tagging
- Reconstruct the stop mass to separate from t-tbar
- Limits are set in the plane of neutralino mass versus stop mass

CDF Gluino-Mediated Sbottom Production



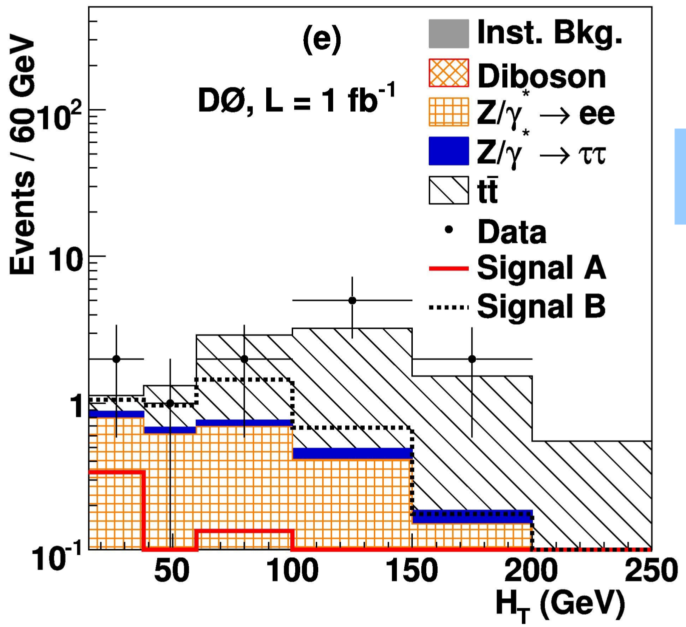
2.5 fb^{-1}



- Produce 2 gluinos, each decay to 2*b* + neutralino, resulting in 4*b* + MET final state
- Require jets > 25 GeV, MET > 70 GeV, divide into 1-tag/2-tag samples
- 2 NN's – one for QCD backgrounds, one for SM backgrounds
- Limits set on gluino cross section versus mass and gluino mass – sbottom mass plane
  - Cross section constrained to be less than 40 fb for sbottom mass of 250 GeV

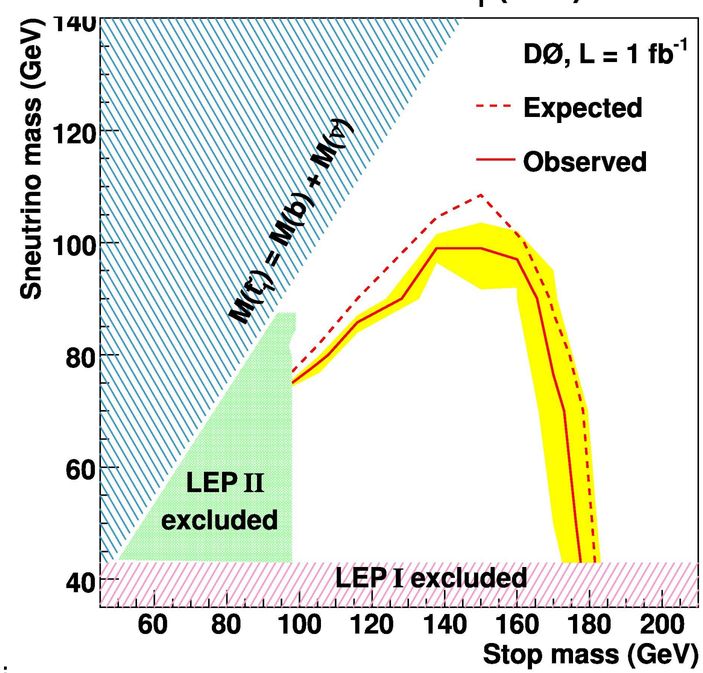
DØ stop in dileptons

- Assume 2 stops produced, each decay to *b*+*l*+sneutrino (assume BR=1)
  - Search in eμ and ee final states
- Require e(μ) > 15(8) GeV, >= 1 jet > 15 GeV, MET > 15-30 GeV
- Use kinematics and b-tagging (in ee) to separate from SM background, divide into bins of S_T, H_T
- Set limits in stop mass – sneutrino mass plane
- Exclude stop < 175 GeV for large Δm



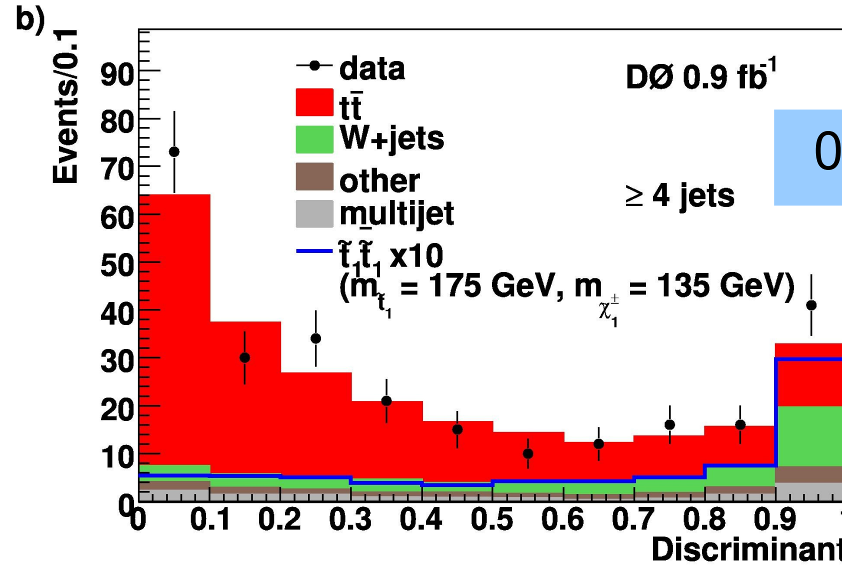
1.0 fb^{-1}

arXiv: 0811.0459, submitted to PLB

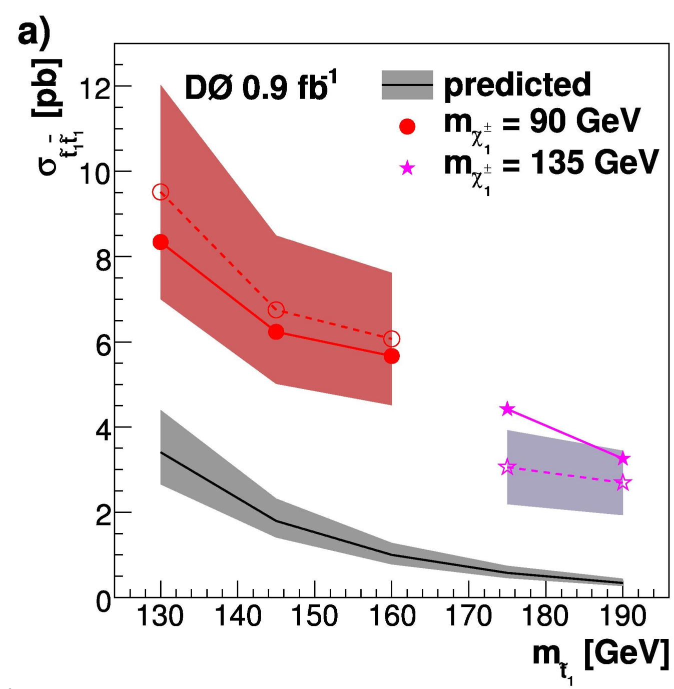


DØ stop in lepton+jets

- Assume two stops produced, each decay to *b* and lightest chargino (which then decays to W and lightest neutralino)
  - Mimics ttbar lepton+jets channel
- Require e/μ > 20 GeV, MET > 20-25 GeV, 3 jets >15 GeV
- Use multivariate likelihood discriminate to separate from ttbar background
- Set cross section limits for different chargino and neutralino masses (factor 2-13 above theory prediction)



0.9 fb^{-1}

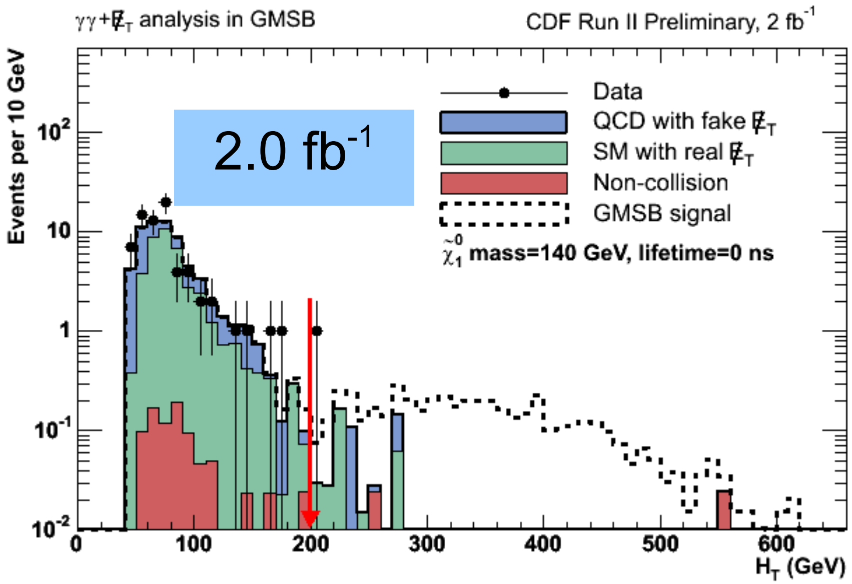


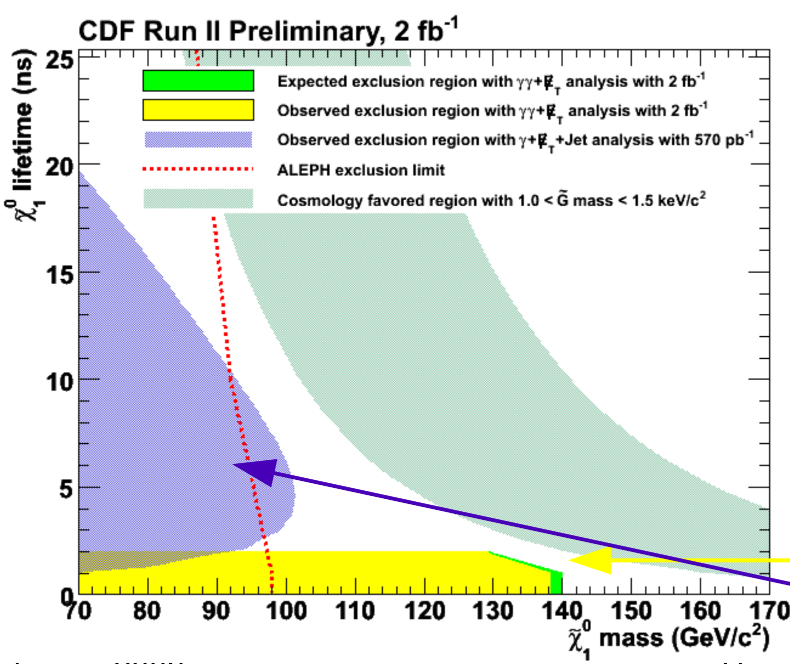
arXiv: 0901.1063, submitted to PLB

GMSB

- In gauge-mediate supersymmetry breaking, SUSY is broken in a hidden sector. This breaking is then communicated to the SM via messenger fields and standard gauge interactions.
- The LSP is the gravitino
- SUSY particles will eventually decay to the LSP through the next-to-lightest SUSY particle (NLSP)
  - NLSP can be the lightest neutralino or a slepton (usually the lightest stau)
  - NLSP decays to LSP can be suppressed, resulting in long NLSP lifetimes!
- If the NLSP is the neutralino, the typical signature is photons + MET (+ X)

CDF diphoton search





- Produce a chargino and a neutralino, which decay to produce two photons and gravitinos (MET)
- Require 2 photons > 13 GeV, MET signif > 3, H_T > 200 GeV, photons not back-to-back
- Limits set on lightest neutralino mass versus lifetime
- Exclude neutralinos < 138 GeV for prompt decays

Background Source	Expected Rate±Stat±Sys
Electroweak	$0.39\pm0.14\pm0.11$
QCD	$0.10\pm0.10\pm0.00$
Non-Collision	$0.049\pm0.042\pm0.028$
Tri-Photon	$0.00\pm0.180\pm0.035$
Wrong Vertex	$0.081\pm0.081\pm0.008$
Total	$0.62\pm0.26\pm0.12$

Observe 1 data event

This analysis

Delayed photons PRL **99**, 121801 (2007)

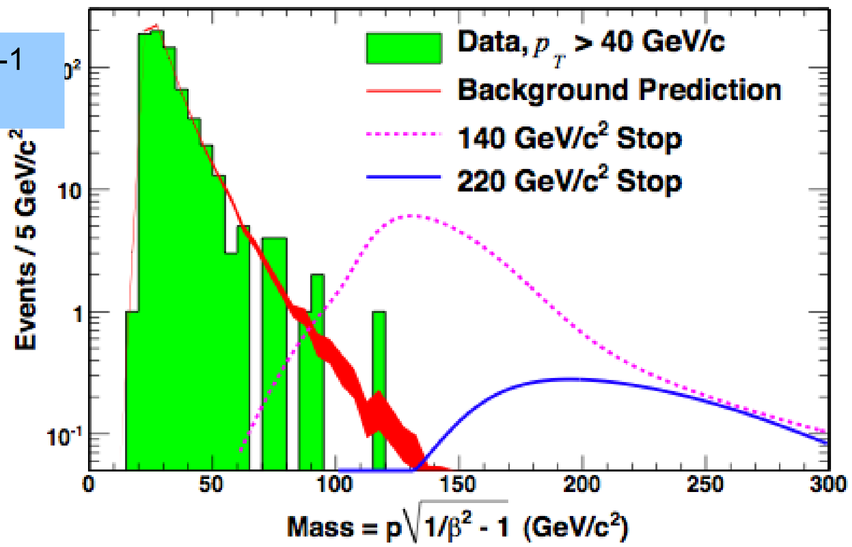
Long Lived Particles

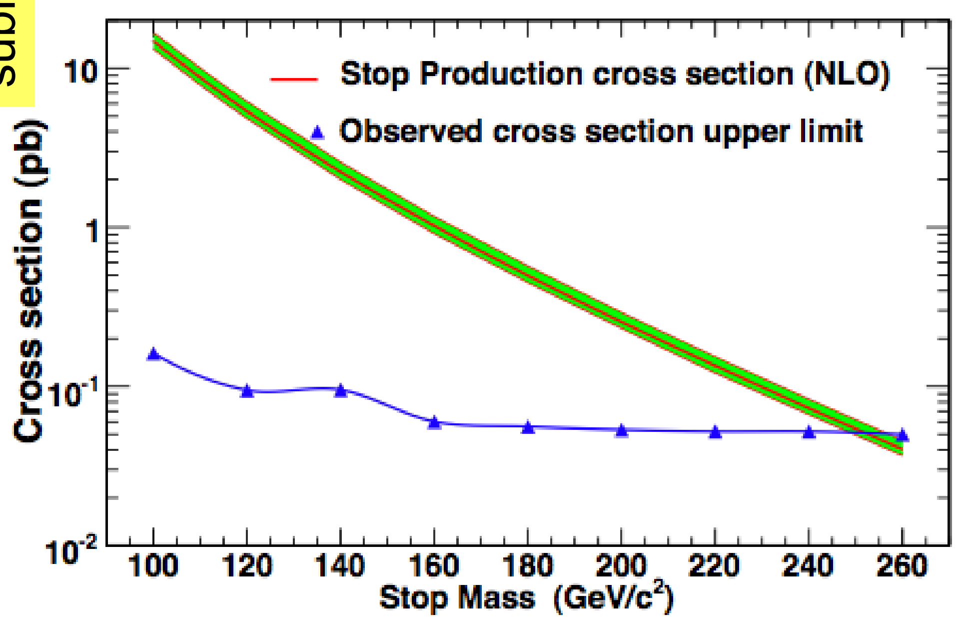
- Particles can be long-lived when their only allowed decay is suppressed. SUSY examples are
  - Stop if decays suppressed by kinematics
  - GMSB with stau NLSP (if stau→gravitino decays suppressed)
  - Lightest charginos if they are nearly mass degenerate with lightest neutralino
- Signature depends on the lifetime
  - Decays inside the detector produce displaced vertices or “kinked” tracks
  - Decays outside the detector can result in “slow muons” if particles are highly penetrating

CDF Charged Massive Stable Particles

1.0 fb^{-1}

arXiv: 0902.1266, submitted to PRL



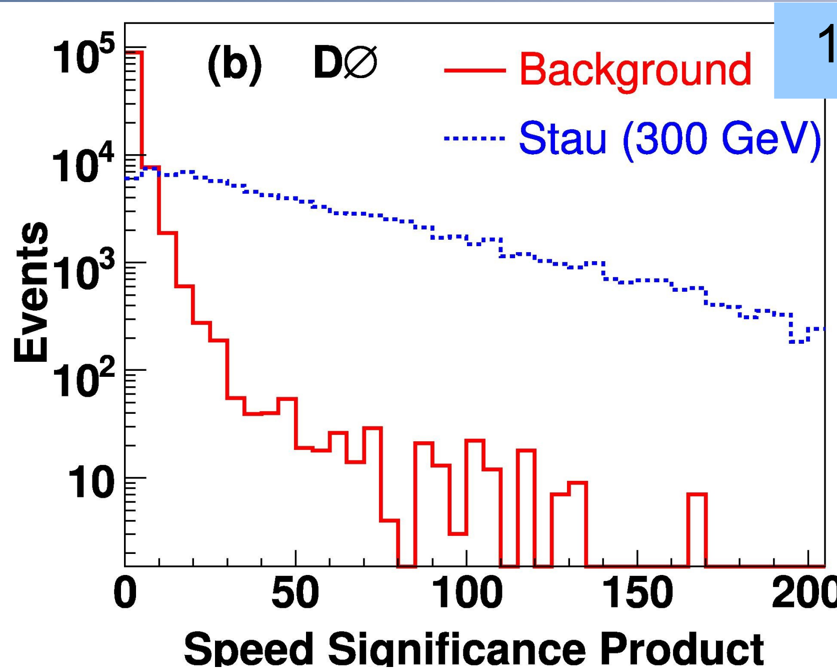


- Look for slow, ionizing particles that pass through the entire detector
- Use CDF TOF detector to measure speed, get mass from speed and track momentum
- For $|\eta|<0.7$, $p_T>40$, $0.4<\beta<0.9$, and $m_{meas}>100$GeV, exclude
  - σ < 10 fb (weak)
  - σ < 48 fb (strong)
- Exclude stable stops below 249 GeV

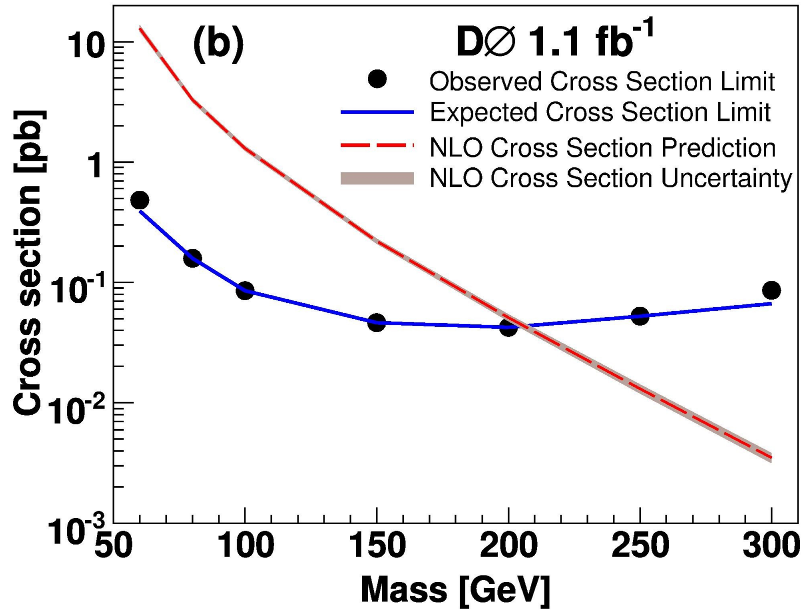
DØ Charged Massive Stable Particles

- Look for pairs of "slow muons" using timing in muon system to measure the speed
- Background is instrumental only and is estimated from data
- No excess observed, so limits set on stau cross section and lightest chargino mass
- Exclude gaugino-like charginos below 206 GeV and higgsino-like charginos below 171 GeV

1.1 fb^{-1}



arXiv: 0809.4472, submitted to PRL

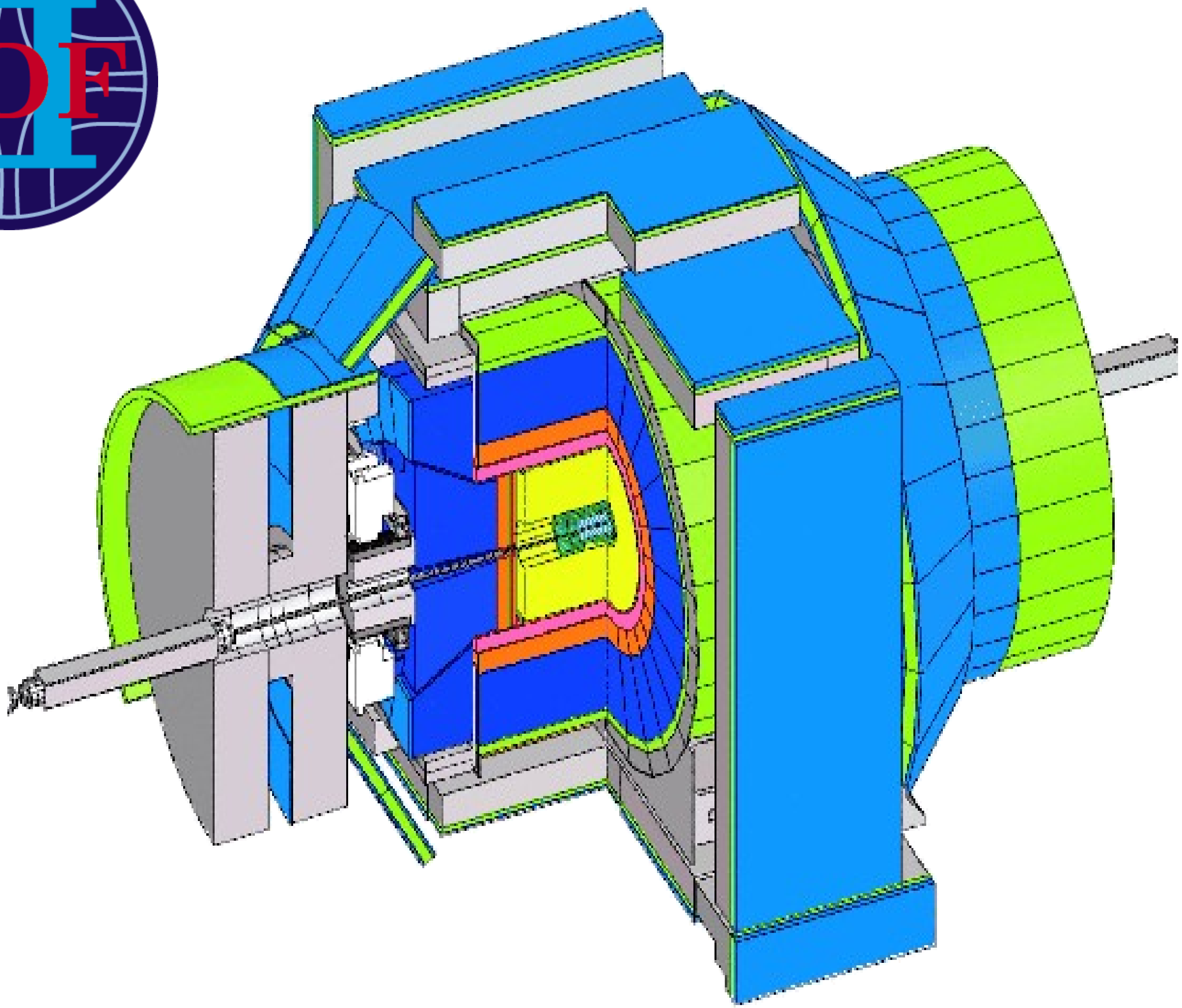


Summary

- I've only been able to highlight some of the most recent SUSY results from the Tevatron
  - Didn't include RPV SUSY results, MSSM Higgs results
- For a complete list, each experiment has a website with all public results:
  - http://www-cdf.fnal.gov/physics/exotic/exotic.html
  - http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
- CDF/DØ combined limits for squarks/gluinos and trileptons are in progress
- Both experiments have 5 fb^{-1} of recorded data and continue to take high-quality data, so stayed tuned for updated results!

Backup Slides

CDF Detector



Electron acceptance:
$|\eta| < 2.0$

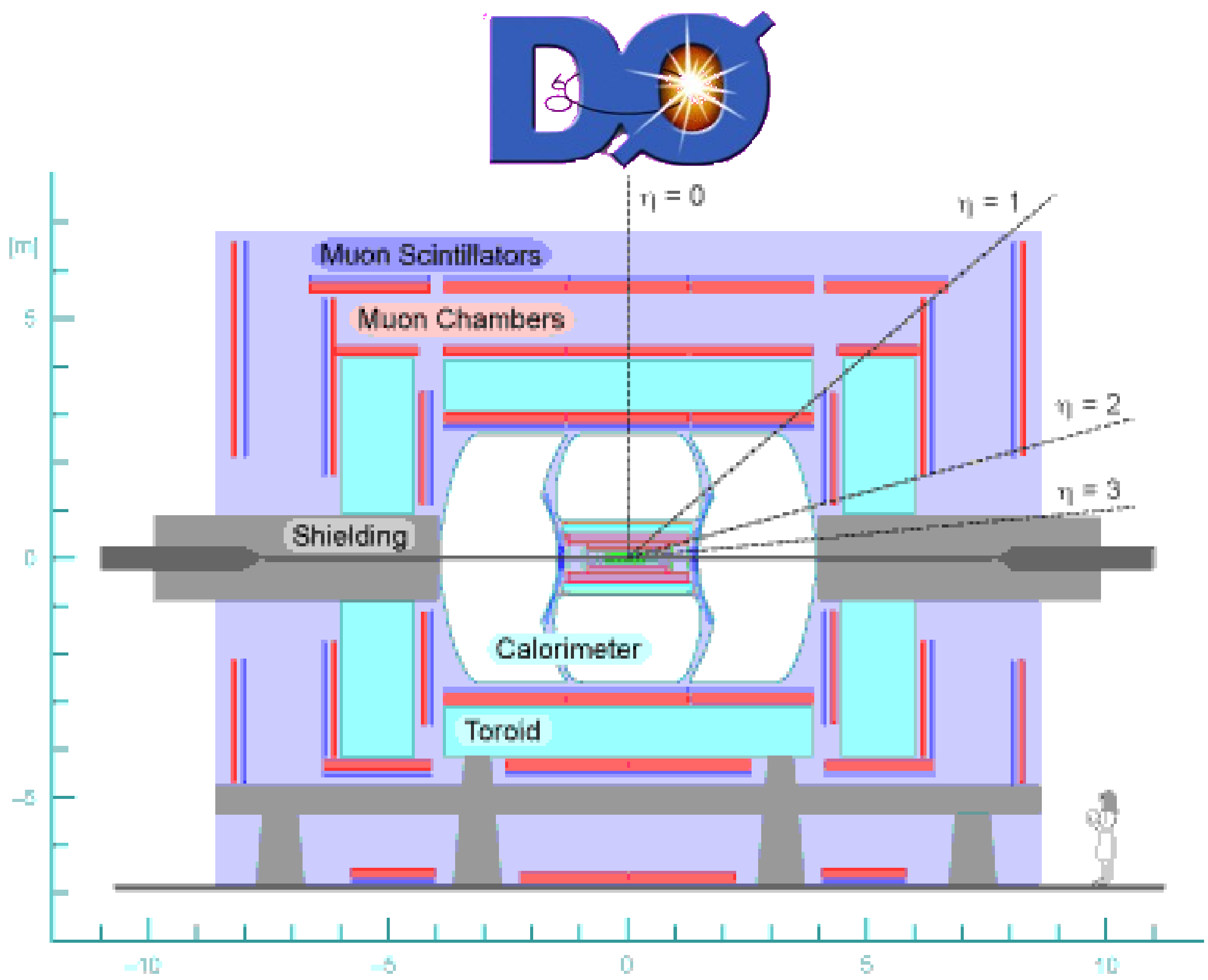
Muon acceptance:
$|\eta| < 1.5$

Silicon tracking:
$|\eta| < 2.0$

Calorimetry:
$|\eta| < 3.6$

Excellent tracking!

DØ Detector



Electron acceptance:
$|\eta| < 3.0$

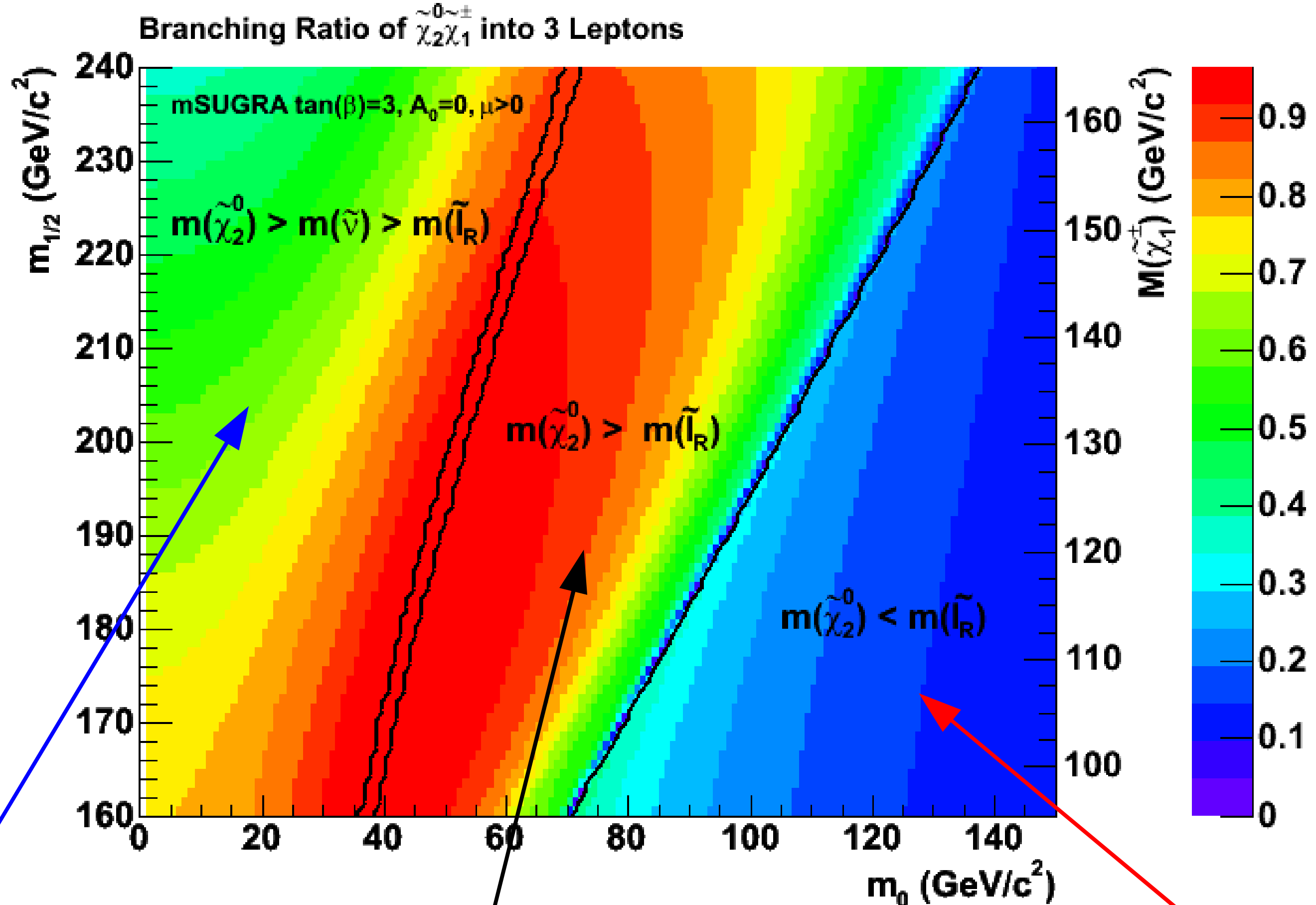
Muon acceptance:
$|\eta| < 2.0$

Silicon tracking:
$|\eta| < 3.0$

Calorimetry:
$|\eta| < 4.2$

Excellent muon system and calorimeter!

Trilepton Decays



Decays to sneutrinos open up, reducing BR to charged leptons

Maximum BR to charged leptons. Charginos/neutralinos decay through sleptons. tau decays of chargino important. Third lepton very soft near right-hand line

Three-body decays of charginos/neutralinos (through W/Z) dominate

DØ Trilepton Selection

TABLE I: Selection criteria for the $\mu\mu\ell$, $ee\ell$ and $e\mu\ell$ analyses (all energies, masses and momenta in GeV, angles in radians) for the low-p_T selection and high-p_T selection, see text for further details.

	Selection	$\mu\mu\ell$ low p_T	$\mu\mu\ell$ high p_T	$ee\ell$ low p_T	$ee\ell$ high p_T	$e\mu\ell$ low p_T	$e\mu\ell$ high p_T
I	$p_T^{\ell 1}$, $p_T^{\ell 2}$	>12, >8	>18, >16	>12, >8	>20, >10	>12, >8[a]	>15, >15
	$m_{\ell_1 \ell_2}$[b]	$\in [20, 60]$	$\in [0, 75]$	$\in [18, 60]$	$\in [0, 75]$	–	–
II	$\Delta\phi_{\ell_1 \ell_2}$	<2.9	<2.9	<2.9	<2.9	–	–
	$\not{E}_T$	>20	>20	>22	>20	>20	>20
	Sig($\not{E}_T$)	>8	>8	>8	>8	>8	>8
	$m_T^{\min}$	>20	>20	>20	>14	>20	>15
III	jet-veto H_T	–	<80	–	–	–	–
IV	$p_T^{\ell r}$	>5	>4	>4	>12	>6	>6
	$m_T^{\ell r}$	>10	>10	>10	>10	>10	>8
V	$m_{\ell_{1,2}, tr}$	$\notin [80, 110]$	–	–	–	<70	<70
VI	anti W	–	–	tight likelihood[c]	–	tight likelihood[d] hit in 2 inner layers[d] very tight muon isolation[e] $\sum_{0.05<\Delta\mathcal{R}<0.4} p_T^{\text{track}}$ <1	
	$\not{E}_T \times p_T^{\ell r}$	>200	>300	>220	–	–	–
VII	p_T^{bal}	<4	<4	<4	<4	<2	<2

[a] $p_T^{\ell 1}$ and $p_T^{\ell 2}$ are electron and muon p_T, respectively.
[b] ℓ refers to the two identified leptons
[c] for $p_T^{\ell r}$ <15 GeV
[d] for $m_T^{\mu} \in [40, 90]$ GeV
[e] for $m_T^{e} \in [40, 90]$ GeV

Selection for eel, eμl, and μμl.

Selection for μτl and μττ

TABLE II: Criteria for the $\mu\tau\ell$ and $\mu\tau\tau$ selections (all energies, masses and momenta in GeV, angles in radians), see text for further details.

	Selection	$\mu\tau\ell$		$\mu\tau\tau$
I	$p_T^{\ell 1}$, $p_T^{\ell 2}$		>15, >8[a]	
II	$\Delta\phi_{\ell_1 \ell_2}$		<2.9	
	$\not{E}_T$		>20	
	Sig($\not{E}_T$)		>8	
	m_T^{μ}		>20	
III	jet-veto H_T		<80	
IV	$p_T^{\ell r}$	>3	$p_T^{\tau 2}$	>4
	$\Delta\phi_{tr, \not{E}_T}$	>0.5	$\Delta\phi_{\tau_2, \not{E}_T}$	>0.5
V	$m_{\ell_{1,2}, tr}$	<60		<60
	anti W	likelihood		likelihood
VI			$NN_{\tau_1} \times NN_{\tau_2}$	>0.7
VII	$\not{E}_T \times p_T^{\ell r}$	>300	p_T^{bal}	<3.5

[a] $p_T^{\ell 1}$ and $p_T^{\ell 2}$ are muon and τ lepton p_T, respectively.

“High-p_T” and “low-p_T” selection (based on two SUSY benchmark models) optimized for each channel

Stop Decays

		Decay	Kinematic
2-body	1	$\tilde{t}_1 \to t\,\tilde{\chi}^0_i$	$m_{\tilde{t}_1} > m_t + m_{\tilde{\chi}^0_i}$
	2	$\tilde{t}_1 \to b\,\tilde{\chi}^+_j$	$m_{\tilde{t}_1} > m_b + m_{\tilde{\chi}^+_j}$
	3	$\tilde{t}_1 \to c\,\tilde{\chi}^0_i$	$m_{\tilde{t}_1} > m_{\tilde{\chi}^0_i}$
3-body	4	$\tilde{t}_1 \to bW\tilde{\chi}^0_i$ $m_{\tilde{t}_1} > m_W + m_{\tilde{\chi}^0_i}$	$m_t + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_{\tilde{b}} + m_W > m_{\tilde{t}_1}$ $m_b + m_{\tilde{\chi}^+_j} > m_{\tilde{t}_1}$
	5	$\tilde{t}_1 \to bH^+\tilde{\chi}^0_i$ $m_{\tilde{t}_1} > m^+_H + m_{\tilde{\chi}^0_i}$	$m_t + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_{\tilde{b}} + m_W > m_{\tilde{t}_1}$ $m_b + m_{\tilde{\chi}^+_j} > m_{\tilde{t}_1}$
	6	$\tilde{t}_1 \to b\ell\tilde{\nu}_\ell$	$m_{\tilde{t}_1} > m_b + m_{\tilde{\nu}_l}$
	7	$\tilde{t}_1 \to b\tilde{\ell}\nu_\ell$	$m_{\tilde{t}_1} > m_b + m_{\tilde{l}}$
4-body	8	$\tilde{t}_1 \to b\tilde{\chi}^0_i f\bar{f}'$ $m_{\tilde{t}_1} > m_b + m_{\tilde{\chi}^0_i}$	$m_t + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_W + m_b + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_{\tilde{b}} + m_W + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_b + m_{\tilde{\chi}^+_j} > m_{\tilde{t}_1}$ $m_W + m_b + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_t + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_{H^+} + m_b + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_{\tilde{b}} + m_{H^+} + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_b + m_{\tilde{\chi}^+_j} > m_{\tilde{t}_1}$ $m_{H^+} + m_b + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$ $m_b + m_{\tilde{\chi}^+_j} > m_{\tilde{t}_1}$ $m_{\tilde{f}} + m_{\tilde{\chi}^+_j} + m_{\tilde{\chi}^0_i} > m_{\tilde{t}_1}$

Table I: Stop decays in the MSSM with R-parity conservation.

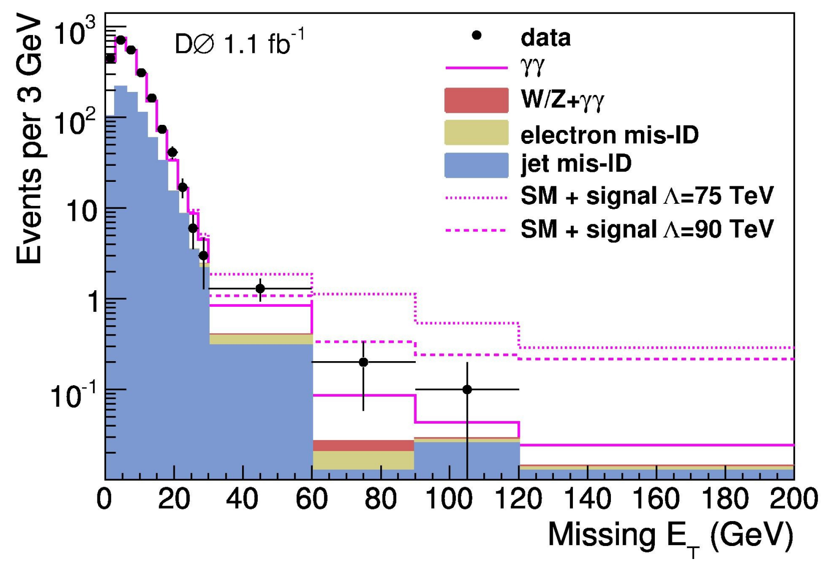
Decay	Final State $\tilde{t}_1\bar{\tilde{t}}_1$
$\tilde{t}_1 \to c\,\tilde{\chi}^0_1$	2 (c)-jets + $\not{E}_T$
$\tilde{t}_1 \to b\,\tilde{\chi}^+_1$ $\tilde{\chi}^+_1 \to W^*\tilde{\chi}^0_1$	2 b-jets + 2 leptons + $\not{E}_T$ 2 b-jets + 1 light-jet + 1 lepton + $\not{E}_T$ 2 b-jets + 2 light-jets + $\not{E}_T$
$\tilde{\chi}^+_1 \to \tilde{\ell}\nu_l$	2 b-jets + 2 leptons + $\not{E}_T$
$\tilde{t}_1 \to bW\tilde{\chi}^0_1$	2 b-jets + 2 leptons + $\not{E}_T$ 2 b-jets + 1 light-jet + 1 lepton + $\not{E}_T$ 2 b-jets + 2 light-jets + $\not{E}_T$
$\tilde{t}_1 \to b\ell\tilde{\nu}_\ell$	2 b-jets + 2 leptons + $\not{E}_T$
$\tilde{t}_1 \to b\tilde{\chi}^0_1 f\bar{f}'$	2 b-jets + 2 leptons + $\not{E}_T$ 2 b-jets + 1 light-jet + 1 lepton + $\not{E}_T$ 2 b-jets + 2 light-jets + $\not{E}_T$

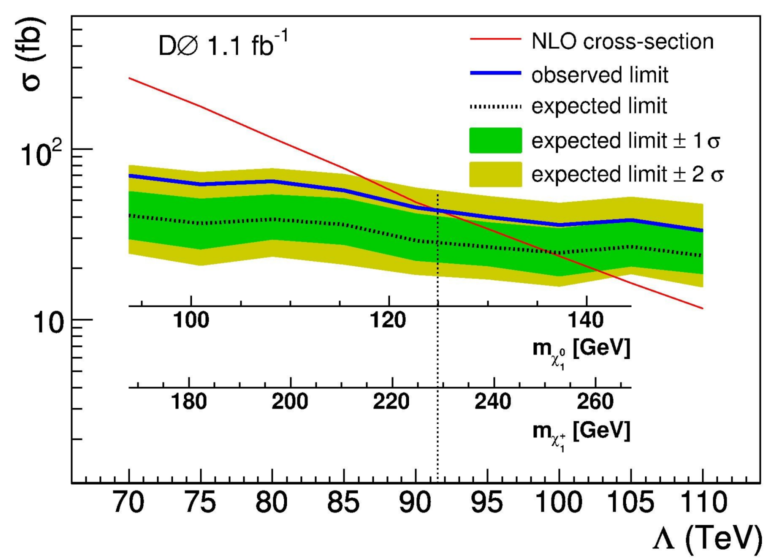
DØ Diphoton Search

PLB **659**, 856 (2008)

1.1 fb^{-1}

- Assume the NLSP is the neutralino, which decays to a photon and a gravitino. This produces a 2 photon + MET signature
  - Assume prompt decays
- Require 2 photons > 25 GeV
- Most troublesome backgrounds are jets and electrons faking photons (estimated from data)
- Set limits on chargino and neutralino masses
- Exclude neutralino < 125 GeV and chargino < 229 GeV





SUSY Higgs Searches

- H^+ in ttbar (1.0 fb^{-1})
- $h \rightarrow \tau_\mu \tau_{had}$ (1.2 fb^{-1})
- Neutral higgs in multi-b (2.6 fb^{-1})
- MSSM higgs in $\tau\tau$ (2.2 fb^{-1})
- Neutral higgs in $\tau_\mu \tau_{had}$+b (1.2 fb^{-1})
- H^+ in tb (0.9 fb^{-1})
  - arXiv: 0807.0859 (submitted to PRL)

- H+ in top decays (2.2 fb^{-1})
- MSSM higgs in bb (2.0 fb^{-1})
- MSSM higgs in $\tau\tau$ (1.8 fb^{-1})

RPV SUSY

- It is usually assumed that SUSY models conserve *R-parity*
  - Results in stable LSP and sparticles produced in pairs
- But, there is no reason that R-parity needs to be absolutely conserved
  - Can be violated with either lepton- or baryon-number violating terms
  - There are limits from (for example) flavor-changing neutral currents, so the amount of R-parity violation should be small
- With RPV interactions, LSP isn't stable and single SUSY particles can be produced

CDF High-Mass Resonances Decaying to Lepton Pairs

$e\tau$ channel						
signal mass (GeV/c^2)	mass cut (GeV/c^2)	SM background events	observed events	exp. signal events	exp. limit (pb)	obs. li (pb)
100	> 80	332.4 ± 13.1	343	827.1 ± 60.0	21.09	21.16
200	> 160	22.7 ± 1.4	21	116.4 ± 6.8	1.02	0.96
300	> 230	5.0 ± 0.5	5	31.8 ± 1.6	0.19	0.19
400	> 280	2.1 ± 0.4	2	10.9 ± 0.5	0.096	0.092
500	> 310	1.4 ± 0.3	2	3.9 ± 0.1	0.069	0.077
600	> 340	1.0 ± 0.3	0	1.3 ± 0.05	0.055	0.039
700	> 360	0.9 ± 0.2	0	0.4 ± 0.02	0.055	0.040
800	> 360	0.9 ± 0.2	0	0.1 ± 0.004	0.050	0.037

$\mu\tau$ channel						
signal mass (GeV/c^2)	mass cut (GeV/c^2)	SM background events	observed events	exp. signal events	exp. limit (pb)	obs. limit (pb)
100	> 80	153.1 ± 10.8	135	548.2 ± 48.8	14.76	13.01
200	> 160	9.3 ± 1.3	2	87.2 ± 5.9	0.66	0.26
300	> 220	2.6 ± 0.5	1	24.1 ± 1.4	0.19	0.16
400	> 240	1.8 ± 0.4	0	8.6 ± 0.4	0.12	0.093
500	> 280	1.0 ± 0.3	0	2.8 ± 0.1	0.081	0.080
600	> 320	0.6 ± 0.2	0	0.91 ± 0.04	0.072	0.056
700	> 350	0.4 ± 0.2	0	0.28 ± 0.01	0.065	0.053
800	> 370	0.4 ± 0.2	0	0.08 ± 0.003	0.062	0.052

$e\mu$ channel						
signal mass (GeV/c^2)	mass cut (GeV/c^2)	SM background events	observed events	exp. signal events	exp. limit (pb)	obs.limit (pb)
100	> 90	22.8 ± 2.4	22	3029.2 ± 114.8	0.45	0.43
200	> 190	3.2 ± 0.5	3	405.9 ± 12.8	0.062	0.058
300	> 280	0.6 ± 0.2	0	98.0 ± 2.8	0.032	0.024
400	> 360	0.2 ± 0.2	0	27.9 ± 0.7	0.024	0.022
500	> 450	0.1 ± 0.1	0	8.3 ± 0.2	0.021	0.020
600	> 500	0.06 ± 0.1	0	2.6 ± 0.07	0.021	0.020
700	> 550	0.05 ± 0.09	0	0.9 ± 0.02	0.020	0.020
800	> 600	0.04 ± 0.08	0	0.2 ± 0.01	0.019	0.018

1.0 fb^{-1}

- Single sneutrino produced in lepton-flavor violating RPV interaction, decays to pairs of leptons
- Use eμ, eτ, μτ final states
- Exclude sneutrino masses below
  - 586 GeV in eμ
  - 487 GeV in eτ
  - 484 GeV in μτ

DØ Scalar Sneutrino in eμ

PRL **100**, 241803 (2008)

1.0 fb^{-1}

- Produce a single sneutrino via a lepton-number violating RPV interaction, then decays to an electron and a muon.
- Main background is SM diboson production
- Observe 68 events, expect 59.2±5.3 from backgrounds.
- Single would show up as peak in the eμ mass spectrum
- Set limits on two RPV couplings (versus sneutrino mass)